# WATER OPERATION AND MAINTENANCE

BULLETIN NO. 136

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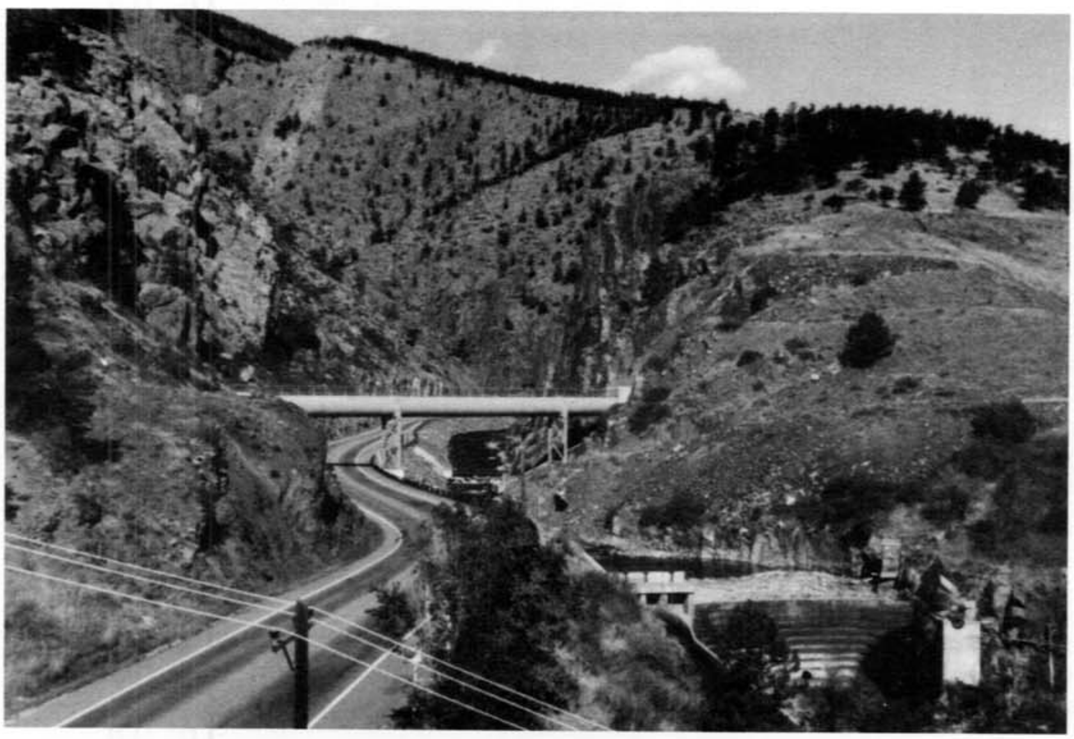

## IN THIS ISSUE

OPERATION AND MAINTENANCE OF INVERTED SIPHONS

**UNITED STATES DEPARTMENT OF THE INTERIOR**
**Bureau of Reclamation**

The Water Operation and Maintenance Bulletin is published quarterly for the benefit of those operating water supply systems. Its principal purpose is to serve as a medium of exchanging operation and maintenance information. It is hoped that the reports herein concerning laborsaving devices and less costly equipment and procedures will result in improved efficiency and reduced costs of the systems for those operators adapting these ideas to their needs.

To assure proper recognition of those individuals whose suggestions are published in the bulletins, the suggestion number as well as the person's name is given. All Bureau offices are reminded to notify their Suggestions Award Committee when a suggestion is adopted.

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Land Technical Services
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Cover photograph:

Big Thompson Siphon, as it crosses the Big Thompson River at the mouth of the canyon. This feature is part of the Colorado-Big Thompson Project.



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# WATER OPERATION AND MAINTENANCE
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## INTRODUCTION

The primary purpose of this feature bulletin is to provide assistance to the various water-user groups that operate and maintain inverted siphons in their project areas. You may find that these suggestions are also applicable to other project facilities operated and maintained by the water-user entities. Please note that care should be exercised when applying the O&M (operation and maintenance) suggestions identified in this bulletin to other unrelated project facilities.

This feature bulletin was written for O&M personnel, although it does contain information designers may find useful in their work.

The authors would like to thank Messrs. Sam Shimamoto (Missouri Basin Region), Ron Effertz (Lower Colorado Region), Merle Turley (Lower Colorado Region), Fred Lasko (Lower Colorado Region), Robert Strand (E&R Center), James Warden (E&R Center), Jerry Schaack (E&R Center), and Vern Yocom (E&R Center) for providing comments and suggestions used in this bulletin.

# OPERATION AND MAINTENANCE (O&M) OF INVERTED SIPHONS

by

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and

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## I. Types of Inverted Siphons

The Bureau of Reclamation (Reclamation) uses a variety of materials as components in constructing, operating, and maintaining inverted siphons, which are also classified as closed conduits (exhibit 1). The use of these materials is due primarily to economic, construction, and maintenance considerations, as well as their flexibility and ease of use in the field by construction and maintenance forces. Precast reinforced concrete pressure pipe (PCP) and asbestos-cement pressure pipe are used quite frequently with the PCP type—the most commonly used of all types. Although reinforced plastic mortar-lined pressure pipe and woodstave pipe have been used in the past, they are no longer designed or manufactured in the United States.

The above pressure pipes are classed with respect to the equivalent amount of earth cover and/or wheel loads over them, as well as the internal hydrostatic head acting within the conduit. To differentiate the classes of pipe, Reclamation designated a letter symbol followed by a numeric rating. For example, the letter A, B, C, or D designates the external load equivalent to 5, 10, 15, or 20 feet of earth cover, respectively. The number associated with the letter symbol, such as 25, 50, 75, 100, 125, or 150, designates the internal hydrostatic head rating in feet of water to the centerline of the pipe. As an example, a Class D-50 pressure pipe is one in which the corresponding equivalent external load is 20 feet with an internal hydrostatic head of 50 feet. When a number precedes the letter symbol, such as 72D-50, this represents a 72-inch internal diameter pipe with the aforementioned loading.

All of the above types of pipe presently used by the E&R Center have rubber gaskets or welded joints. Generally, no matter how "tight" these joints are sealed, leaks can occur. The most critical time is shortly after construction when the pipe is prone to the effects of settlement of the siphon during and after the operational break-in period.

Whether welded or riveted, as done in the past (photographs 1 and 2) steel pipes are also used and may consist of all-steel construction with the following coating and lining options:

1. Cement-mortar coating and cement-mortar lining

2. Coal-tar enamel coated and wrapped and cement-mortar lining, and

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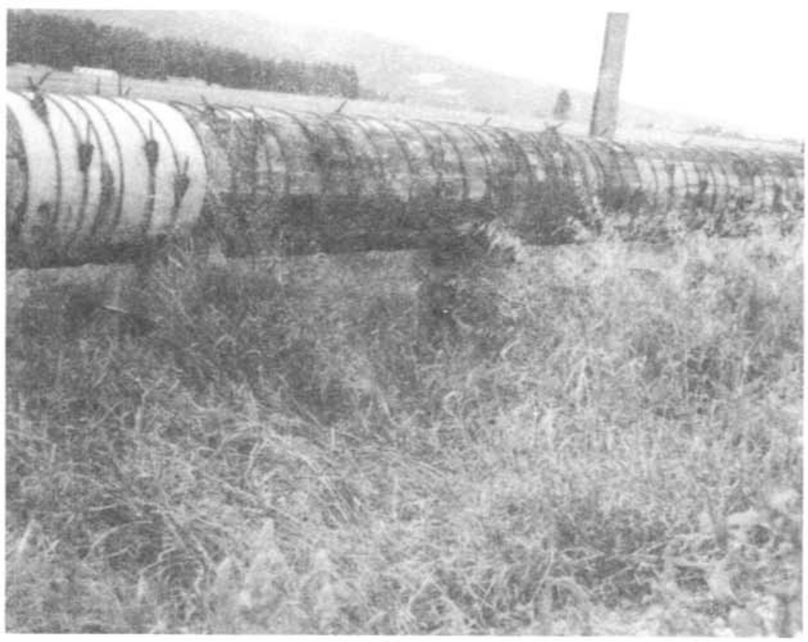
3. Plastic-tape coating and cement-mortar lining.

The use of steel, although special in its application and function, generates unusual maintenance problems and requires special consideration when making repairs.

**Photograph 1 - Malheur River Siphon showing the welded sections - Owyhee Project.**

Another type of material still in use in some areas of the northwest is woodstaves, which pre-date the 1940's (photograph 3). Abundance of wood products for construction and maintenance, as well as the low roughness coefficient of wood, are some of the primary reasons why this material was used.

**Photograph 2 - Bully Creek Siphon** showing the riveted sections - Vale Project.



**Photograph 3 - Woodstave pipe still in use in the Northwest.**

## II. Operation

The following identifies methods and procedures to consider in operating these structures to prolong the useful life of inverted siphons. If a Designers' Operating Criteria (DOC) or designers' assumptions is available, it should be used. In cases where these instructions are not available, past experience should be documented and used as a guideline.

Inverted siphons are some of the most ignored inline canal/lateral structures for a number of reasons. The main reason is that if the siphons are properly designed, constructed, and operated, problems associated with these structures are essentially nonexistent. Another reason is that, since the structure in most cases is covered, problem areas cannot be readily observed by direct inspection. Remember that if there is a variation from the designed operation, problems will eventually surface. These problems are not noticeable at first and usually manifest themselves in the form of reduced capacity and/or higher upstream water surface elevations. Reasons for restrictions in a siphon are rarely examined until all possible solutions for the expected problems have been exhausted.

The initial filling procedure for siphons should be made with small flows ranging between 10 and 20 percent of design capacity. Check this procedure carefully with the DOC, if available, or with the operational history based on sound experience and judgment. If there are structural problems, the small flow will reduce the effects of damage should failure occur. Reduced filling of the siphon prevents entrainment of air which could become compressed and damage the siphon. From an operational standpoint, lower flows facilitate removal of "debris" upstream from the inlet structure which could plug the siphon during filling operations.

In the northern latitudes, care should be exercised when filling, especially when ice is present. Water demand for municipal, industrial, and electrical generation purposes occurs year round in some areas. Operation during this time is very critical due to sub-zero temperatures that may cause the formation of ice in the canal, as well as in the siphon.

Large ice chunks entering the siphon may damage the siphon as well as inline appurtenant equipment. If water is required during these cold periods, a minimum flow (lowest flow that will not freeze) must be established in order to provide enough latent heat to prevent the water from freezing while in transit. If flow is reduced below the allowable minimum and freezes, the system could be rendered inoperable for the duration of the winter. Serious structural damage could result from the effects of freezing. Minimum flow criteria are usually based on engineering judgment and previous "hands-on" operational experience.

In southern latitudes, initial filling should follow the general procedures mentioned above. Since freezing rarely occurs in these latitudes, most problems in these latitudes are due to sediment and windblown debris transported into the canal system.

In all geographical areas, the end of an irrigation season presents potential problems, such as buildup of sediment, debris, rocks, etc., occurring as the flow velocity in the siphon is reduced. Lower flows reduce the sediment-carrying capacity of water as the particles (depending on velocity, slope of siphon, particle weight, and size) will fall out of suspension and deposit at the lowest point of the siphon. If rocks or other debris are allowed to enter the siphon during flow periods, there is high probability that even at 100 percent discharge the flow will not clear the siphon of debris. Debris tends to accumulate at low points, bends, or elbows and obstruct the siphon. If the accumulation of debris is not removed, a reduction in capacity will occur which will affect delivery capability of the system. Interior structural damage will also occur in the form of localized erosion as a result of debris buildup and increased flow velocity through the area. Rocks striking or grinding at the interior walls will cause damage. If the above are allowed to continue for a number of years, blowouts and subsequent failure of the siphon may occur.

Dewatering of siphons depends on the type of canal lining used in the irrigation system, soil types, emergency situations, potential damage to the siphon if dewatered, or established operating criteria along with engineering judgment. Dewatering is also dependent on established drawdown rates for lined and unlined canals to prevent failure due to hydrostatic forces behind canal lining or sloughing potential in unlined canals. Other considerations include climatic conditions as well as safety considerations. For example, in areas susceptible to freezing, full or partially full siphons can freeze damaging the siphon as well as appurtenant equipment due to expansion of ice during the freezing process. In such cases, it may be necessary to dewater the siphon to prevent freezing of water inside or immediately outside of the siphon.

Regardless of climatic conditions, consideration must be given to potential safety hazards of siphons, especially near urbanized areas. Operational experience and judgment become very important in deciding whether or not to dewater siphons at these locations. Physical barriers, in the form of bulkheads, may be warranted to prevent access to watered or dewatered siphons at the inlet and outlet structures. The goal is to minimize safety hazards while ensuring structural integrity of the facility which becomes more difficult as urbanization expands into project areas.

## III. Inverted Siphon Problems

Reduction or capacity problems can occur in siphons for a number of reasons. A few examples are: pipe moss (bryozoa), freshwater sponges, chemical precipitates, excessive leakage, improper design, or scour damage (which may increase the roughness coefficient). Fortunately, most of these problems can be corrected.

Partial or total closure of the flow of water is, fortunately, a very remote occurrence. However, as the irrigation project reaches maturity, the opportunity for problems tends to increase for numerous reasons, such as age, phreatic waterflow from the system itself, or from foreign subsurface water that weakens unforeseen geology of the area. Examples are landslides in the area of a siphon inlet, large animals, cars, or other debris that may enter the system (photograph 4). Potential hazards are kept to a minimum if the siphons are cleaned on a periodic basis.

**Photograph 4 - View of the trashrack structure, immediately downstream from a siphon. Fortunately, driver escaped from vehicle prior to passing through siphon. Colorado-Big Thompson Project.**

Leakage from joints is another problem. A leak of this type may seal itself after a period of time. However, if not corrected, differential settlement could occur as a result of consolidation, saturation, soil chemistry (subsidence), or earth movement. Regardless of the cause, any large movement can result in leakage or erosion of backfill material that can be potentially dangerous to the structural integrity of the siphon. Any leakage of water in excess of 5 percent of design discharge should be of concern to the operating entity. The best technique is to repair from the inside, if possible, assuming the pipe diameter will safely permit maintenance forces to make repairs. If not, leakage can be reduced or stopped externally by applying a cement/mortar patch over or around the hole or crack. Other methods may consist of installing a metal band around the crack to hold repair material in place. Bands for this type of repair become expensive if there are numerous cracks in the system.

Small voids in the backfill adjacent to covered siphons are not harmful; however, any large voids that are discovered should be filled by jetting slurry or other suitable backfill material into the void to maintain the integrity of the facility, as well as to reduce potential safety hazards to maintenance personnel.

In areas prone to freeze-thaw conditions, any type of leak should be sealed to prevent frost heave or other deformation problems.

## IV. Maintenance

If the flow capacity is reduced, there are a number of cleaning methods available to perform maintenance and return the siphon to its design capacity. The methods will depend on the type of material used to construct the siphon. Operational constraints, safety constraints, equipment, manpower requirements, and economic limitations must be considered when cleaning siphons.

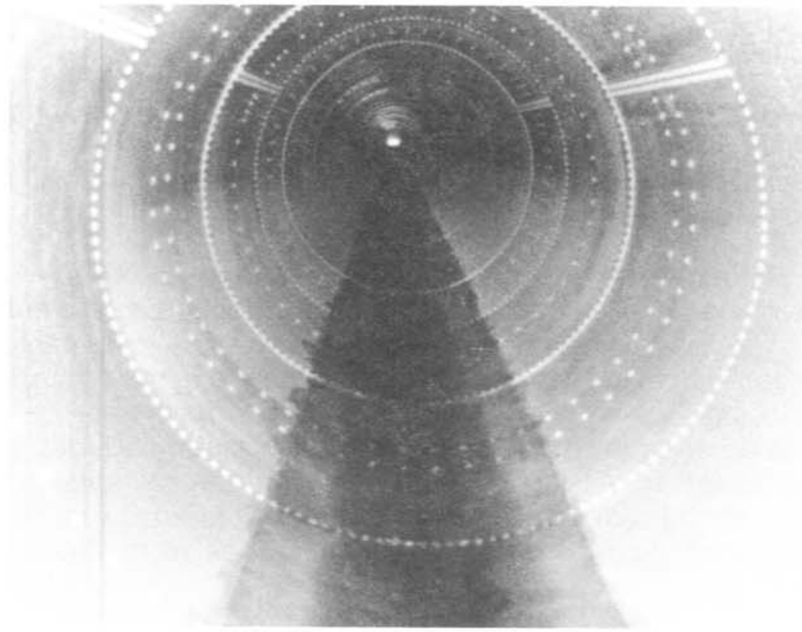
For siphons up to 36 inches in diameter, cleaning can be performed by first forcing "fish" tape through the siphon. A cable can then be attached to a cleaning device and a machine can pull the cleaning device through the siphon. A drag cable should always be attached to the cleaning device in case it becomes lodged in the siphon. This procedure usually works well in siphons with a length of under 50 feet since in most cases, the maximum length that a fish tape can be pulled is approximately 50 feet. In large siphons, manholes can be installed in the top invert of the siphon to guide the tape through or for debris removal. If the siphon requires frequent cleaning, the drag cable can be left inside the siphon and securely attached at both ends to facilitate future cleaning operations.

For siphons larger than 36 inches in diameter, maintenance effort is minimal, except in cases where the cleaning device(s) do not perform adequately due to large accumulations of debris. In such case, it may be necessary to utilize manual labor to physically remove debris. When equipment is used, one should ensure that the total weight distributed over the contact surface does not exceed the equivalent hydrostatic head rating in the conduit.

Other cleaning techniques include roto-rooter type devices, air and/or water jets, brushes, or combinations of any or all of the above. The method used should not cause additional damage to the siphon or pose a safety hazard to personnel. An inspection and a cleaning frequency interval should be established in order to maintain proper operation of the siphon. Intervals will need to be adjusted to suit operation activities of the specific operating entity.

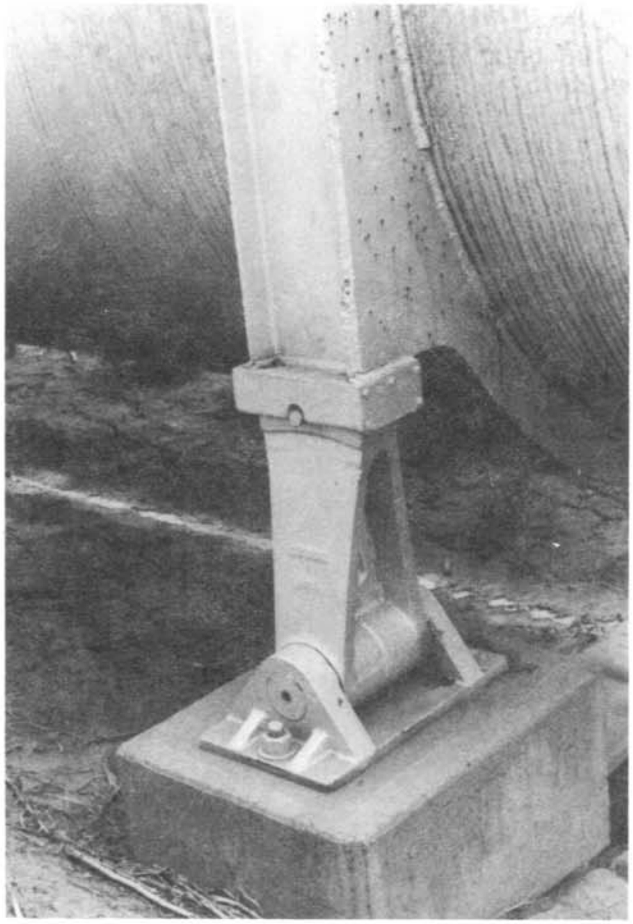
If debris removal or the erosion of interior protective coatings becomes excessive, consideration should be given to installing traps or skimmers at or near the inlet to remove debris before it enters the siphon. Cleaning can then be performed by using mechanical equipment in the more accessible locations outside the siphon.

Repair procedures for siphon leaks entail a wide range of techniques. There are a number of products available which have been designed for repairing siphons. The product instructions should be followed closely to maximize the benefit and to ensure proper safety of maintenance personnel. Repair techniques such as epoxy, vinyl resin, water seal or water plug, quick-set cement mixture, fiberglass, wooden dowels, oakum, hemp fibers, lead wool, and rubber-based products can be used effectively on concrete, steel, and woodstave pipes. Liquid steel, epoxy, and welding combined with the products above are some of the materials and methods used to effect repairs to steel siphons. Photograph 5 is an example where an irrigation district is using fiberglass material applied to the floor of a steel siphon to reduce scour as well as provide a good wear surface (see O&M Bulletin No. 130). In cases where rivets have become scoured to a point where the structural integrity of the pipe is in question, welding the rivet heads can restore the structural integrity of the steel siphon. The installation of fiberglass material over the rivet heads will also reduce the welding frequency.



**Photograph 5 - Interior view of the Bully Creek Siphon showing fiberglass material applied to the floor of riveted siphon - Vale Project.**

When the steel siphon is above ground and incorporates the use of anchor supports with rockers, rollers, or skid plates (photograph 6), special problems may arise. For example, during the nonirrigation season when the siphons are empty, temperature changes may "lift" the siphon off of its supports allowing the rocker arm or the rollers to fall out of position. Upon the resumption of a load, without proper support, the siphon will drop down. Depending on the relative deflection encountered, this would generate stresses within the siphon in the form of "wrinkles" on the top portion of the siphon. There are a number of ways to solve this problem. One suggestion would be to weld a horizontal plate (guide) with a centered hole to the friction pad and weld a vertical rod to the rocker arm. In the event the siphon should "lift," the guide will prevent the rocker arm or rollers from falling out of position. When loading conditions are repeated, the guide will allow the rocker arm or rollers to adjust and center back onto the friction pad. The pin bearing should be lubricated with care. If not done properly, movement of the rocker arm or rollers will be inhibited to such a degree that the stresses and damage will be transferred "along" the rocker and support ring. If the siphons are lifting off the anchor supports, the expansion coupling should be loosened each year after the irrigation season to allow the pipe to move in the expansion coupling. At the beginning of the next irrigation season, the coupling will need to be tightened prior to filling the siphon. In some cases, grease fittings are installed between the coupling flanges to allow the pipe to slip. This will also provide protective coating of the pipe encased inside the coupling.



**Photograph 6 - Rocker support and arm on the Malheur River Siphon - Owyhee Project.**

Protection of interior and exterior metallic surfaces poses another problem. There are a number of products available for protecting these surfaces with each having its own advantages as well as its disadvantages. The paint protection used must be compatible with the intended use of water for which the system was designed.

In cases where pipe moss is prevalent, an approved copper-based paint can be used to control moss. Maximum life of this type of copper-based paint is dependent on the number of coats that are applied to the interior surfaces but varies from 1 to 3 years. It should be noted that algae, per se, does not grow in the absence of light. Algae is essentially a plant which requires sunlight in order to survive. Since there is little or no light available in siphons, only the pipe moss will be prevalent. If algae is found in the siphon, it is attributable to detached moss from exposed portions of the canal system.

In cases where corrosion is prevalent, the use of cathodic protection may be necessary. A qualified corrosion expert should be consulted for proper use of this method and to ensure cathodic protection is warranted. The use of dissimilar metals as replacement parts is the most common problem encountered and should be discouraged and avoided.

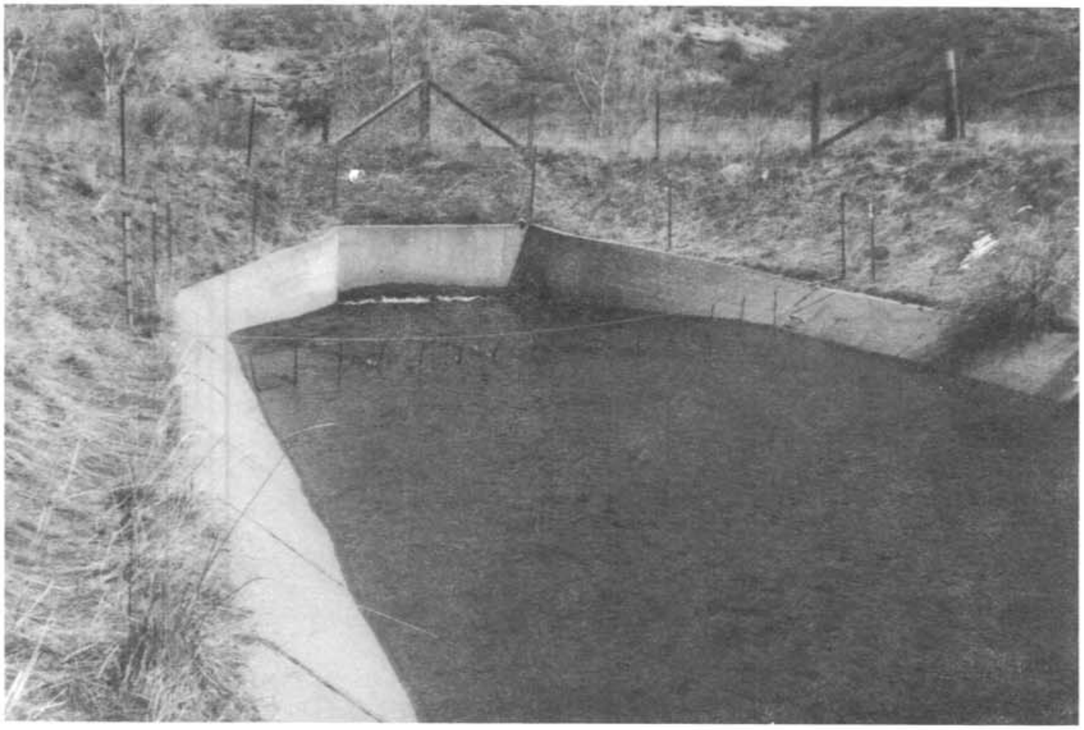
Prior to painting, all surfaces should be properly sandblasted, cleaned, primed, and a sufficient number of coats applied to promote adequate coverage until the next scheduled coating application. Oxidation of exterior paint is the most common deteriorating agent. Paint having this characteristic should be avoided, if possible. Although more expensive, an enamel or nonoxidizing paint can last up to twice as long as oxidizing paint. When applied correctly and allowed to cure, enamel or nonoxidizing paint provides the best protection to exterior surfaces.

## V. Safety Considerations

Safety considerations play an important role in performing O&M functions. Before performing maintenance or inspecting project siphons, they should be completely dewatered. This should be done well in advance to vent and dry the siphon in order to prevent injury to personnel performing inspections or maintenance activities. Once a problem area has been identified for repair, consideration must be given to proper air ventilation when using any type of motorized equipment, cutting or welding apparatus, and painting. All safety standards, practices, and policies must be adhered to at all times in order to protect the personnel performing the inspections or repair activity.

On facilities where there are no trashracks, and their installation becomes necessary, care must be taken to evaluate all alternatives such as existing spill or wasteway capacity and effectiveness with respect to promoting safety to the public. Trashracks are used for two reasons—people safety (O&M or public) and safety of the conveyance system. When considering people safety, trashrack spacing is very critical as they must be narrow enough to prevent the entrance of children and still allow small debris to pass through the openings. If trashracks are necessary, they should be installed at a gentle slope of 4 or 5 to 1. This accomplishes two objectives, it permits people to escape by reducing the effect from being "pinned" to the trashracks by water velocity and allows weeds to move up on the trashrack facilitating removal and reducing the "pile-up." It may become necessary to add sufficient automated devices to protect the investment and system reliability.

In areas where trashracks cannot be installed, safety cables, nets, and ladders must be used. These devices must be installed so they permit proper and safe exit of personnel should they fall into the conveyance or distribution system (photograph 7) and must be installed far enough upstream to avoid the turbulent entrance areas of the inlet. They must also be installed, operated, and maintained in such a way as to optimize their designed intent. Whenever partial flows are encountered, safety cables, ropes, or nets must be adjusted accordingly so that personnel can grab onto them and make their escape.



**Photograph 7 - Safety chain upstream of siphon where driver of car shown in photograph 4 made his escape.**

## VI. Other Appurtenances

At some installations, a provision for air relief valves, vents, or standpipes near the inlet of the siphon may be necessary. These devices extract entrained air or large pockets of air when the entrance condition is particularly turbulent. If large pockets of air are entrained into the water and carried through the siphon, severe surging of water downstream can occur which may damage the siphon or lining, disrupt water service and measurement, cause erosion, and overtop canal linings. Air vacuum valves also may be necessary to introduce sufficient quantities of air to protect the siphon from collapse during dewatering operations. The above devices must be checked periodically to ensure they are operating as designed to prevent potential damage to the siphon due to surging, water hammer, or draining (photograph 8). Remember that air vacuum valves must have at least 15 feet of head above the centerline of the valve to operate satisfactorily; therefore, air valves generally are not installed at the inlet of siphons but are located at the high points along the alignment. If these high points are not at least 15 feet below the hydraulic grade line, then the air vent should be used.

**Photograph 8 - Collapse of pipeline as a result of air vent freezing or being plugged with ice during dewatering. This particular section has been replaced. (Special Note: The control cable (shown on pipeline) should be installed at the downslope side of the siphon (as shown) to prevent damage from falling rocks.)**

Drain or blowoff valves are important devices used primarily for dewatering purposes and should be maintained with as much care as other key appurtenances of the system. These devices play an important role in that their use provides economic and expedient methods of dewatering siphons (exhibits 2 and 3). If valves are not provided, the siphon must be pumped which is a considerable task, especially when large siphons are involved. For flat slope canal systems, cofferdams may be required to prevent pumped water from flowing back into the siphon. This entails an extra cost for maintenance forces and is another reason why maintenance activity is not performed on siphons. Drain valves must also be large enough to permit small rocks and debris to exit freely and to prevent excessive vibration, which could cause fatigue and failure of the valve. They must also be installed in a location where their operation will not be hampered by sediment accumulation or corrosion and will not be subject to damage from flooding such as in a gully, valley, or within a flood zone.

## VII. Other Considerations

Other considerations include close examination or inspection of siphons at the bottom of draws, gullies, or valleys for effects of scour due to storm runoff. Damage as a result of erosion could remove the cover over the siphon and scour the exterior surfaces of the siphon. If the protective cover is removed by erosion, a cover of similar native streambed material and of equivalent weight should be replaced over the siphon or a concrete cap installed over the top to protect it from scour damage. A rock barrier on top, located upstream and downstream of the siphon, could be installed, taking care not to exceed design cover loadings. Any time a protective cover is used, it should be transitioned in such a manner as to avoid any anticipated scour damage. Check dams upstream and downstream may also be installed to reduce erosional damage until a final solution is found.

## VIII. Documentation

Documentation of siphon activities, with respect to O&M, provides a history and record for personnel to use as a general guide for repair activity, on performance of repairs, estimating sediment deposition, and in establishing removal intervals. Photographs incorporated in this document will also provide a visual history to monitor problem areas encountered in O&M activities of siphons and are helpful in recording problem areas throughout its operational history.

EXHIBIT 1

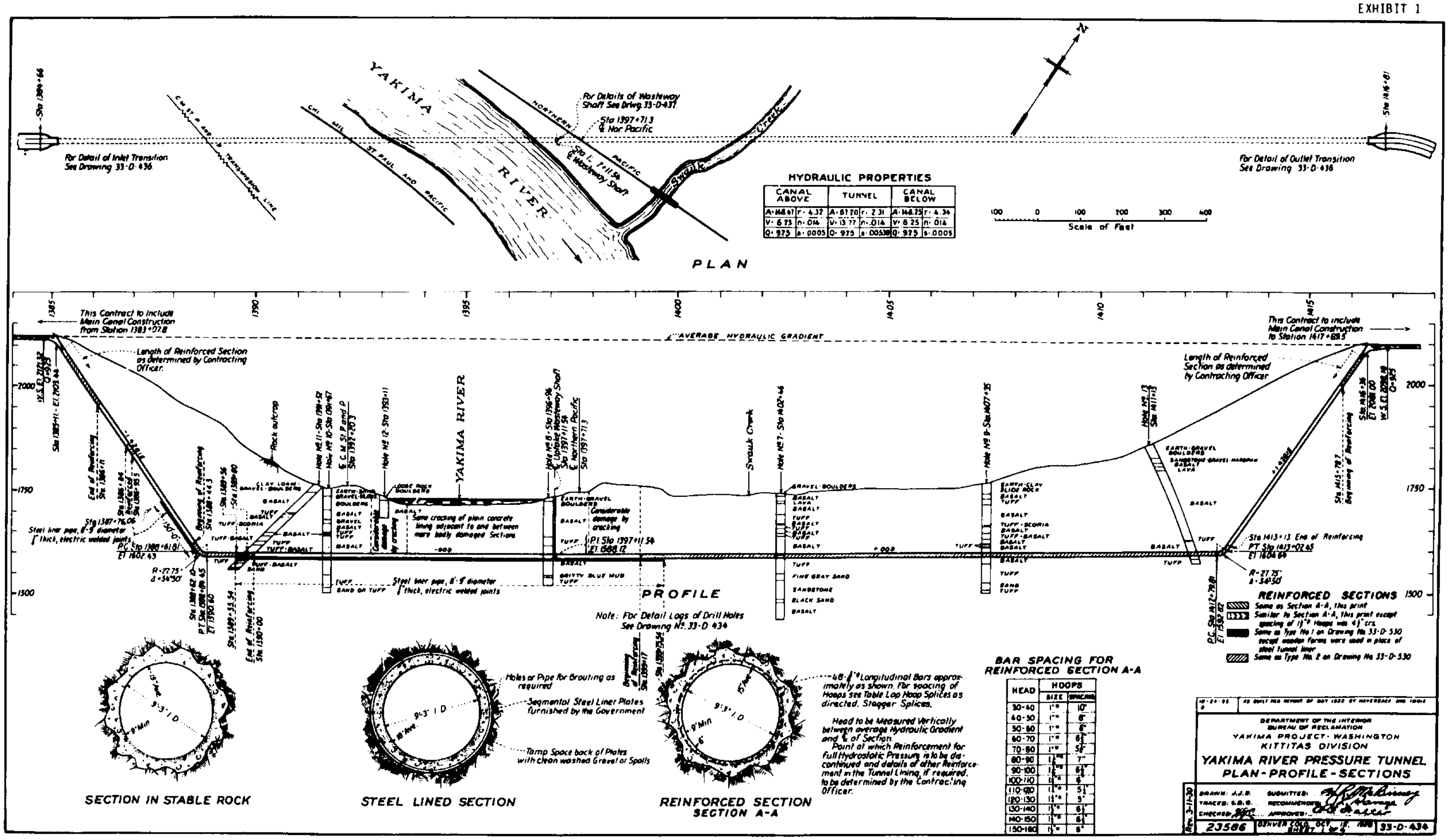



EXHIBIT 1

Drawing No. 33-D-434

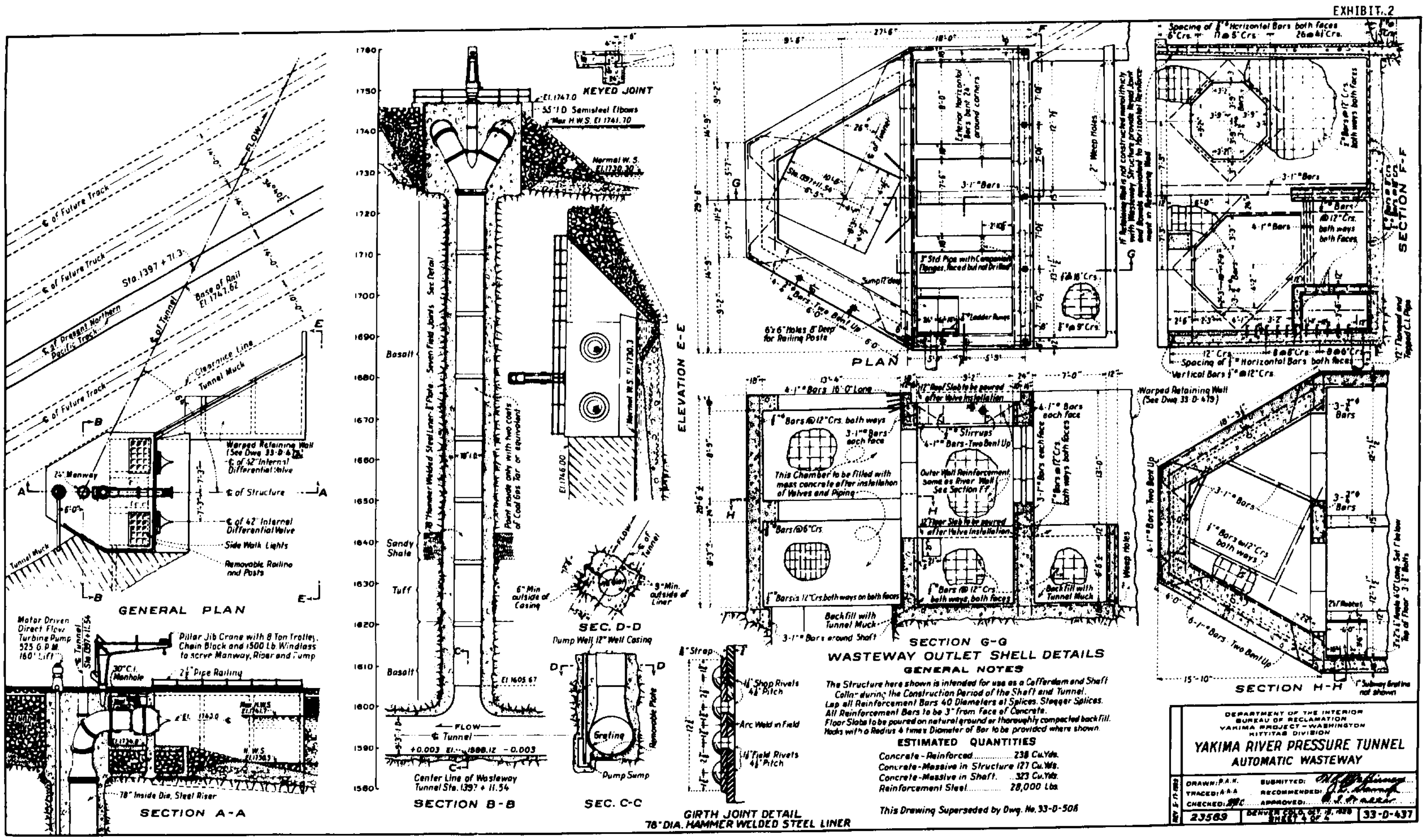



**EXHIBIT 2**

**Drawing No. 33-D-437**

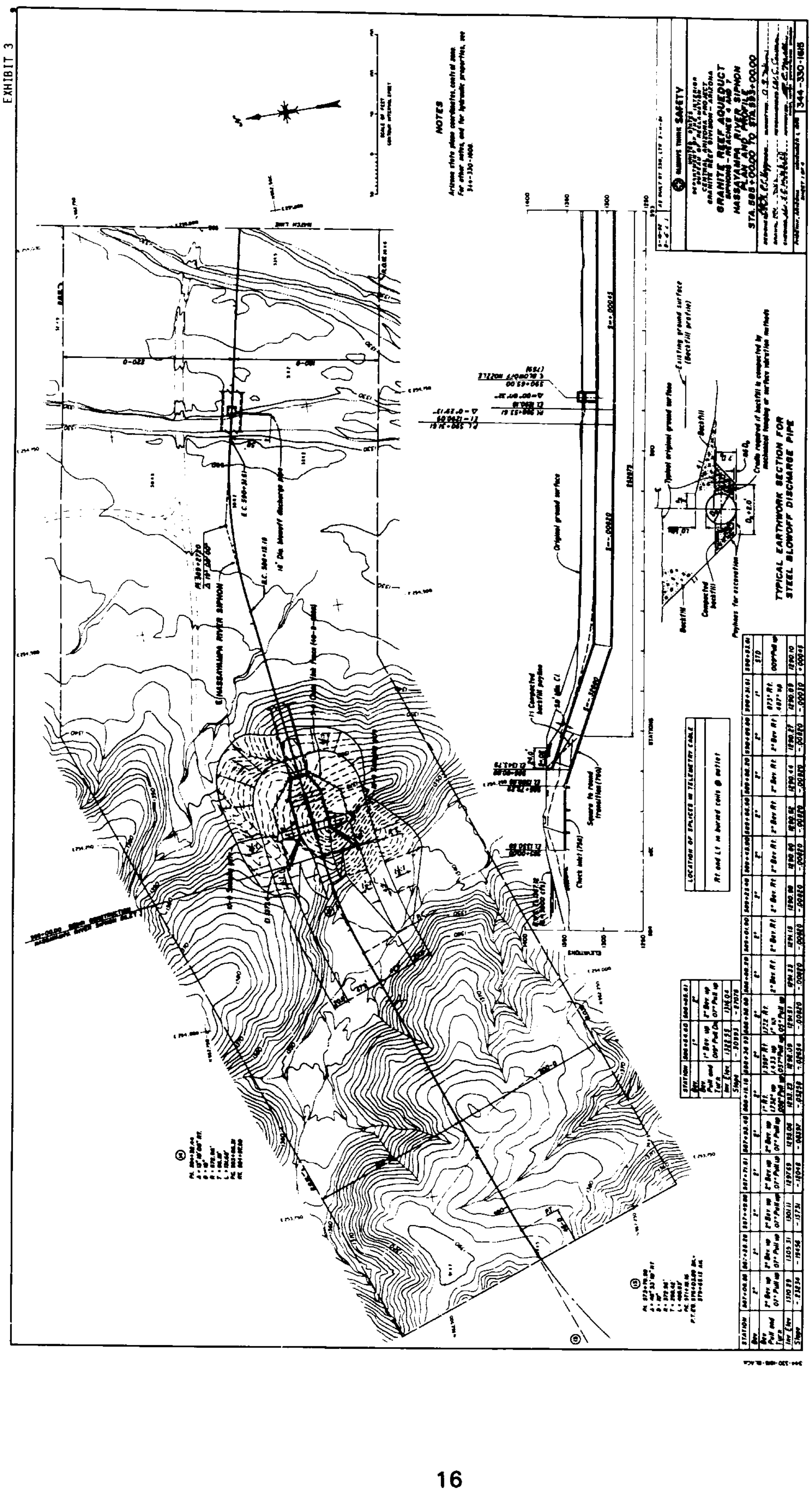



EXHIBIT 3

Drawing No. 344-330-1615


The purpose of this Bulletin is to serve as a medium of exchanging operation and maintenance information. Its success depends upon your help in obtaining and submitting new and useful O&M ideas.

Advertise your district's or project's resourcefulness by having an article published in the Bulletin! So let us hear from you soon.

Prospective material should be submitted through your Bureau of Reclamation Regional Office.

GPO 851-513

**Mission of the Bureau of Reclamation**

*The Bureau of Reclamation of the U.S. Department of the Interior is responsible for the development and conservation of the Nation's water resources in the Western United States.*

*The Bureau's original purpose "to provide for the reclamation of arid and semiarid lands in the West" today covers a wide range of interrelated functions. These include providing municipal and industrial water supplies; hydroelectric power generation; irrigation water for agriculture; water quality improvement; flood control; river navigation; river regulation and control; fish and wildlife enhancement; outdoor recreation; and research on water-related design, construction, materials, atmospheric management, and wind and solar power.*

*Bureau programs most frequently are the result of close cooperation with the U.S. Congress, other Federal agencies, States, local governments, academic institutions, water-user organizations, and other concerned groups.*

A free pamphlet is available from the Bureau entitled "Publications for Sale." It describes some of the technical publications currently available, their cost, and how to order them. The pamphlet can be obtained upon request from the Bureau of Reclamation, Attn D-822A, P O Box 25007, Denver Federal Center, Denver CO 80225-0007.